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A CLOSED-LOOP GAS ANALYZING SYSTEM.(U)

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A CLOSED-LOOP GAS ANALYZING SYSTEM

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A closed-loop gas analyzing system was developed for monitoring concentrations of oxygen and carbon dioxide in the one-atmosphere diving system, "JIM." The gas-analyzing system ensures against loss of gas from a fixed gas volume and affords the option of monitoring the gas concentrations either in the operator's mask or in the cabin. JIM can be monitored by this system either in the laboratory or when submerged at shallow depths.

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A CLOSED-LOOP GAS ANALYZING SYSTEM

Abstract

A closed-loop gas analyzing system was developed for monitoring concentrations of oxygen and carbon dioxide in the one-atmosphere diving system, "JIM." The gas-analyzing system ensures against loss of gas from a fixed gas volume and affords the option of monitoring the gas concentrations either in the operator's mask or in the cabin. JIM can be monitored by this system either in the laboratory or when submerged at shallow depths.

Index Terms: Gas analyzing; oxygen; carbon dioxide; one-atmosphere diving system.

INTRODUCTION

During evaluation of life-support requirements for JIM, a one-atmosphere diving system, the Naval Medical Research Institute designed and developed a closed-loop gas analyzing system. The system was needed for determining the oxygen and carbon dioxide concentrations in JIM's cabin and in the oral nasal mask worn by the operator. Essentially, JIM has a fixed volume of gas, because the available oxygen in the cabin is metabolized by the operator and oxygen is added by an oxygen makeup system that maintains the desired concentration of 21%. The carbon dioxide generated by the operator is absorbed in cannisters filled with baralyme, which are located on both the exhalation and inhalation sides of the mask.

The JIM operator relies upon a Draeger[R] analyzer, which records oxygen concentrations, and a cabin pressure indicator, which shows increases in carbon dioxide. This method is adequate for operational dives, but does not provide sufficient information on gas concentrations for an in-depth evaluation of the life-support system.

METHODS AND MATERIALS

The System

The closed-loop gas analyzing system developed consists of two lengths of 3/16th o.d. Tygon[R] flexible plastic tubing, which channels the gas flowing from the JIM cabin through the monitoring instruments back to the cabin (see block diagram, Fig. 1; figures are in the Appendix). Tygon tubing was put inside a 40-foot* length of hose that served as a carrier and protector; the hose was secured to JIM by a stainless steel hose adapter (manufactured in-house) that penetrated JIM's hull. The surface end of the hose around the Tygon tubes was potted with clear RTV #118 General Electric silicone rubber (Fig. 2); thus, gas leakage was prevented between JIM's cabin and the surface environment.

*Forty feet of hose allows for future shallow submerged testing.

In the JIM system there are two pickup locations for sample gas. One is located in the oral nasal mask (Fig. 3); the other is located in the cabin at the operator's chest level. The two pickup tubes are connected to a Luer two-way valve, which is controlled by the JIM operator (Fig. 4). When the Luer valve is in line with the pickup tube in the oral nasal mask, the operator's inspired and expired oxygen and carbon dioxide concentrations are monitored. When the Luer valve is in line with the pickup tube for the cabin, the oxygen and carbon dioxide concentrations in the cabin are monitored.

Data Collection

The concentration of oxygen is measured with an OM-11 Beckman oxygen analyzer; the concentration of carbon dioxide is measured with an LB-2 Beckman analyzer (Fig. 5). The microcatheter pump in each instrument provides the flow and direction of the gases within the closed loop. For data collection the analyzers are connected to a dual-channel recorder.

During the laboratory testing phase, the JIM system was held in a vertical position and supported by a stand (Fig. 6). The JIM operator was at rest in a standing position throughout the test. The controls for the life-support system were set up for a routine wet working dive; the oxygen was delivered at approximately 1.5 liters/minute.

RESULTS AND DISCUSSION

The lengths of the Tygon tubing through which the test gases flowed were too long to provide an accurate breath-by-breath measurement of carbon dioxide and oxygen. Although the respiration rates could be counted from the chart tracings, some inhalation and exhalation gas mixing took place both in the oral nasal mask and in the tubing. Therefore, the values shown in Fig. 7 represent the highest concentrations of carbon dioxide and oxygen recorded at each exhalation point. Also shown in Fig. 7 are the carbon dioxide and oxygen concentrations in the cabin at the operator's chest level.

Cabin thermal conditions dictated that 1 h was the optimum amount of time that an operator could remain inside JIM during dry laboratory testing. The heat generated by the absorbent cannisters along with the body heat given off by the operator increased the cabin temperature from 78°F to 86°F. Under actual diving conditions, the heat would contribute to the thermal comfort of the operator.

At the end of the 1-h testing period:

- Concentrations of oxygen in the cabin exhibited a slow, steady increase from 20.8% to 29.8%; concentrations of oxygen in the oral nasal mask increased from 19.9% to 42.9%. These increases were a result of the 1.5 liter/minute oxygen injection rate set for the average wet working dive.

- Carbon dioxide concentrations in the cabin increased from 0.3% to 0.32% during the 1-h testing period. The carbon dioxide concentrations in the oral nasal mask reached a low of 4.1% and a high of 4.8%, with a mean of 4.45%.

The accuracy of measurements during the testing period was ensured by calibration of both analyzers immediately before and immediately after the testing period.

CONCLUSIONS

The closed-loop gas analyzing system developed for evaluating JIM's breathing system has proved to be an invaluable tool. Throughout the testing with JIM, continuous accurate monitoring of oxygen and carbon dioxide concentrations was possible. This method of gas monitoring did not interfere with the operator's normal activities, and it should not interfere with JIM's mobility during wet, shallow dives. The system is compact and portable; it should work well in field conditions that can supply AC power for the Beckman instruments.

We anticipate that the closed-loop gas analyzing system will be useful in future evaluations of one-atmosphere diving systems and that it will contribute to life-support technology.

APPENDIX

Figures Relating to Report

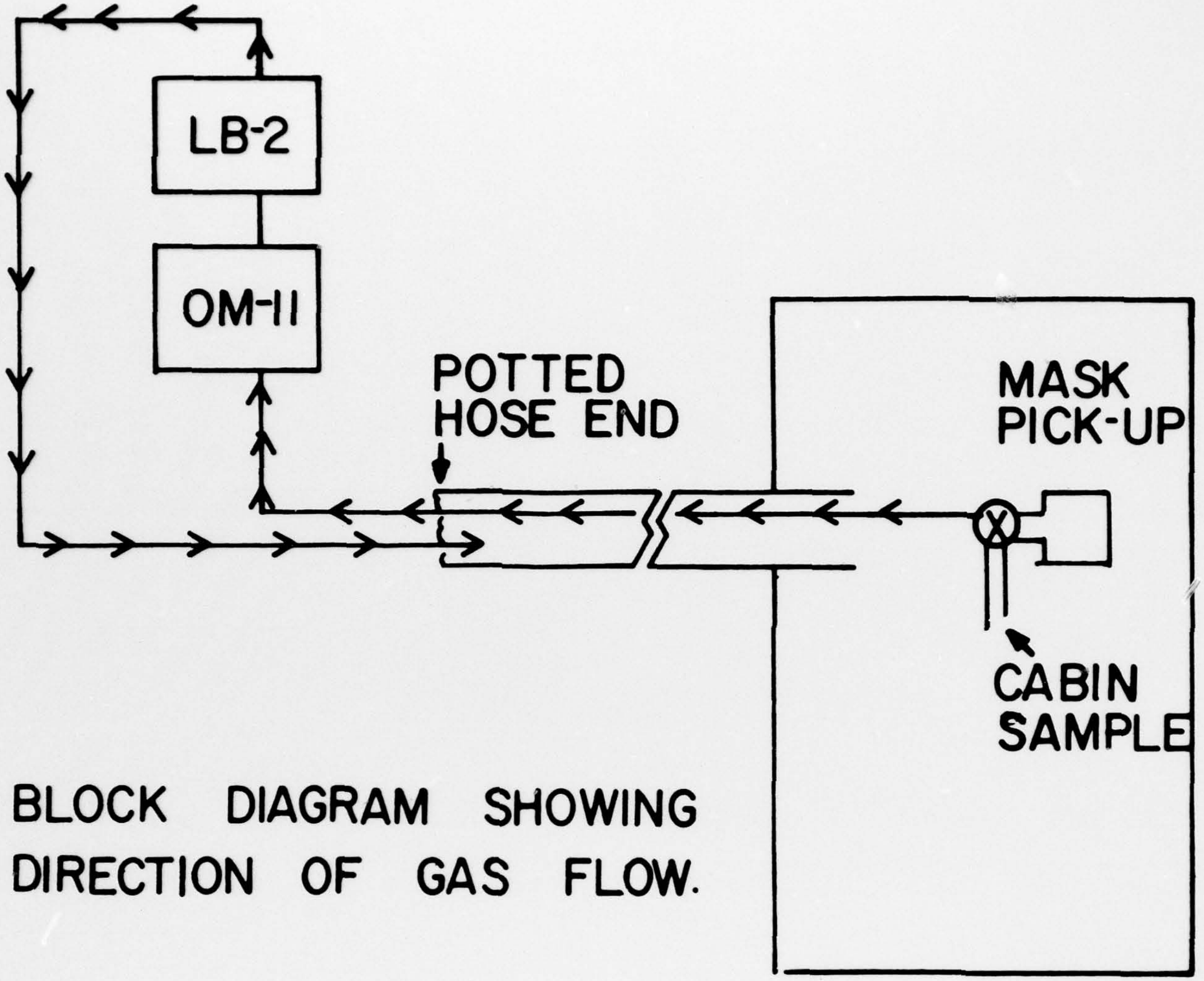

Fig. 1. Block diagram.

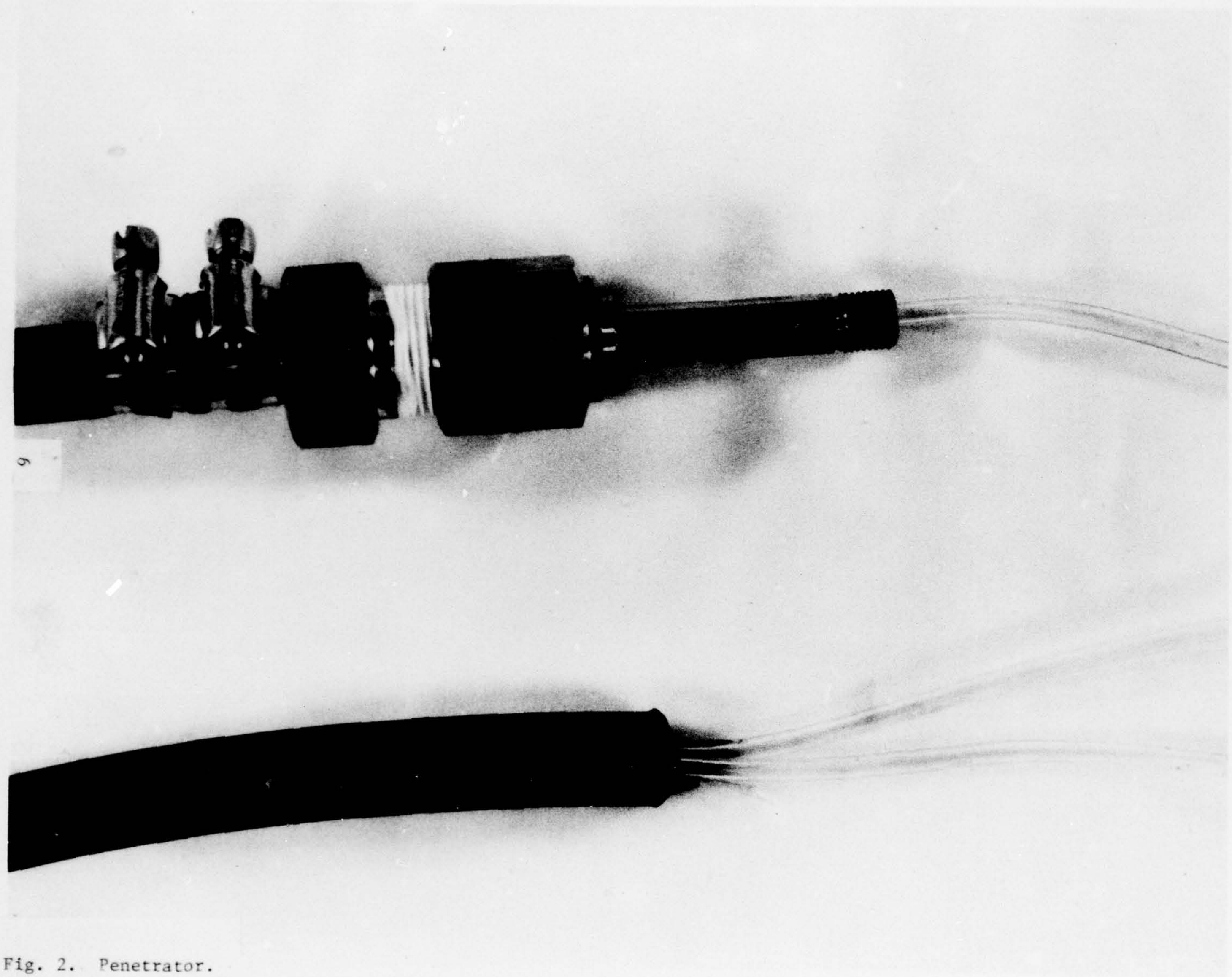

Fig. 2. Penetrator.

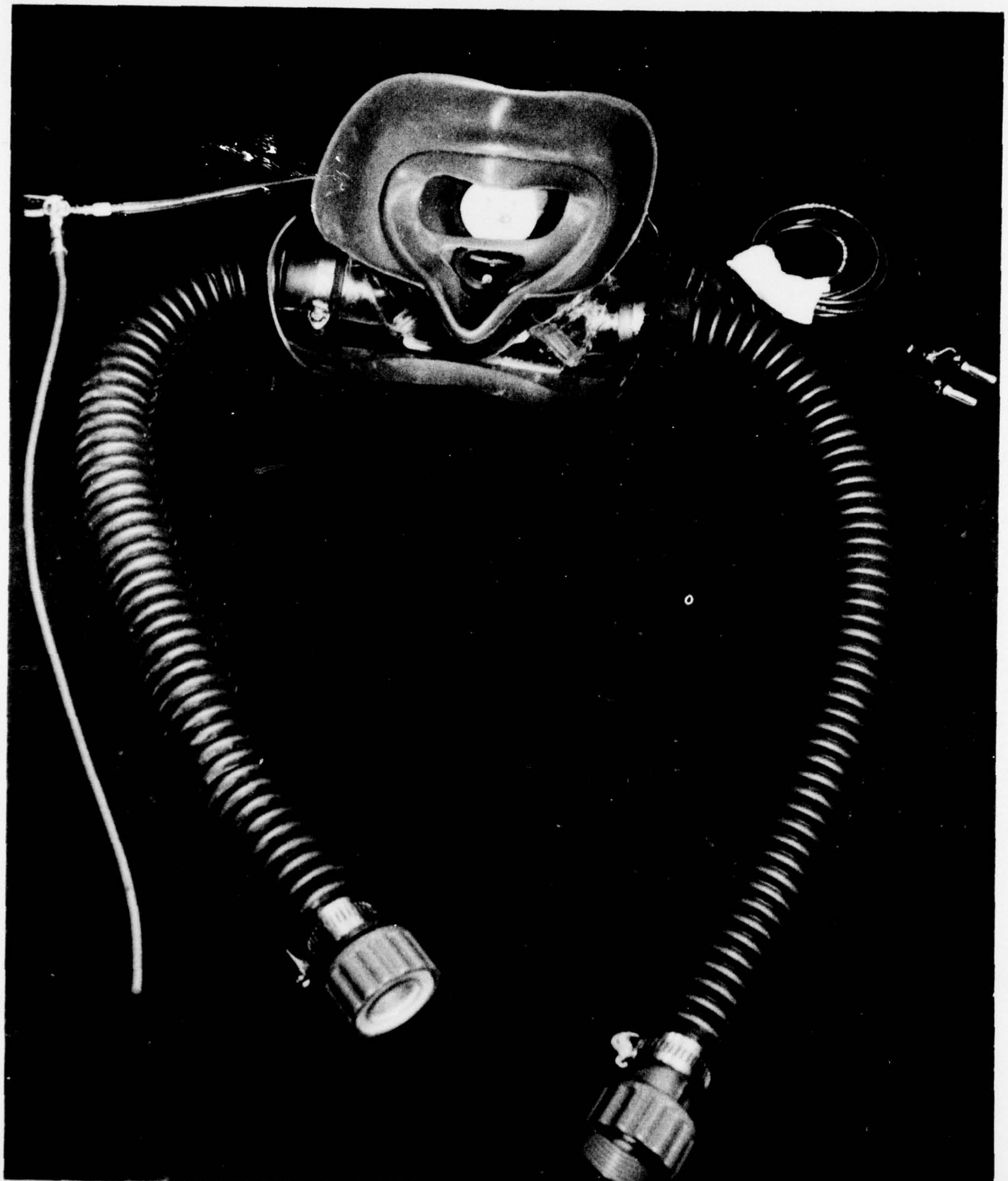

Fig. 3. Mask showing sample pickup.

Fig. 4. Sample pickup valve.

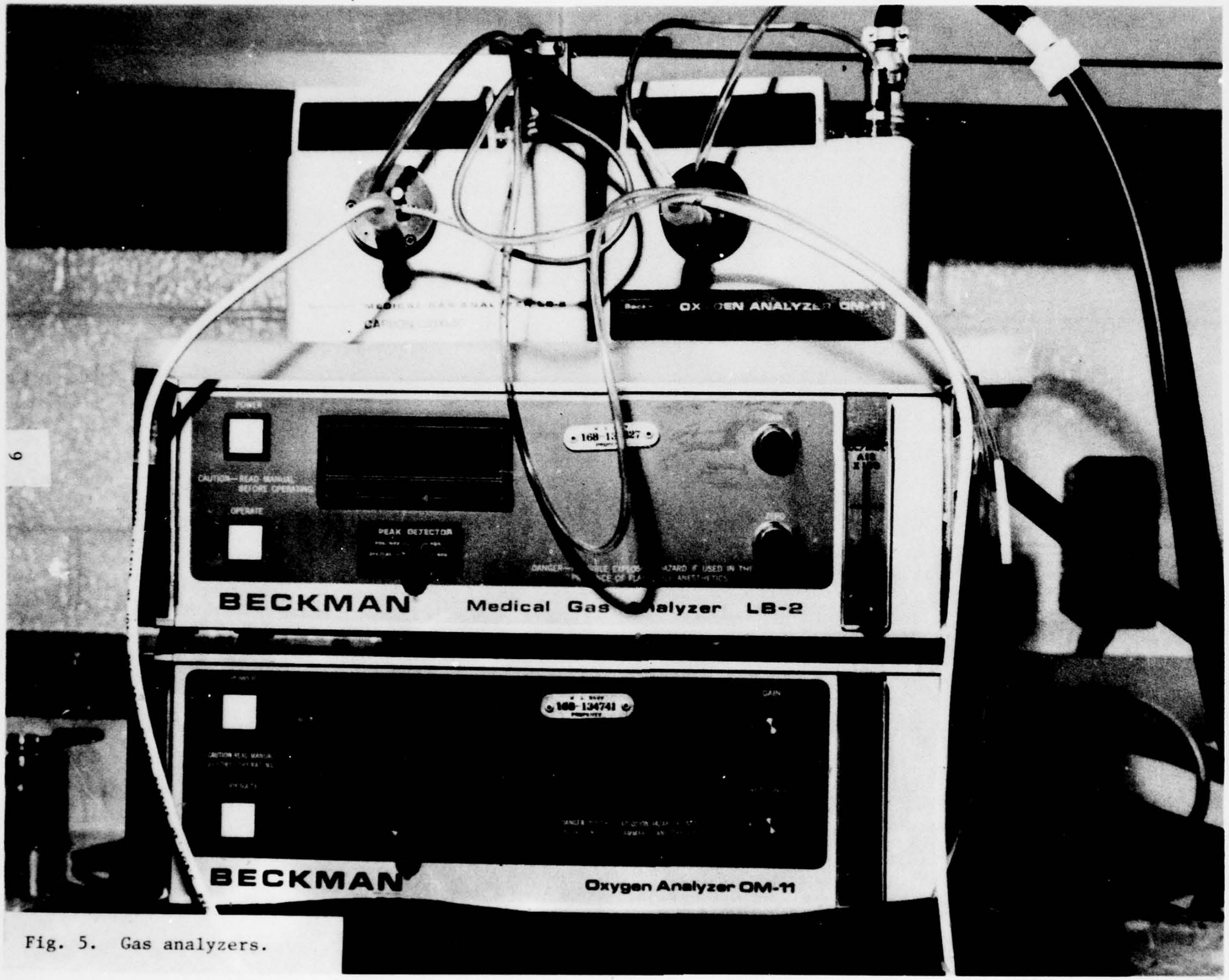

Fig. 5. Gas analyzers.

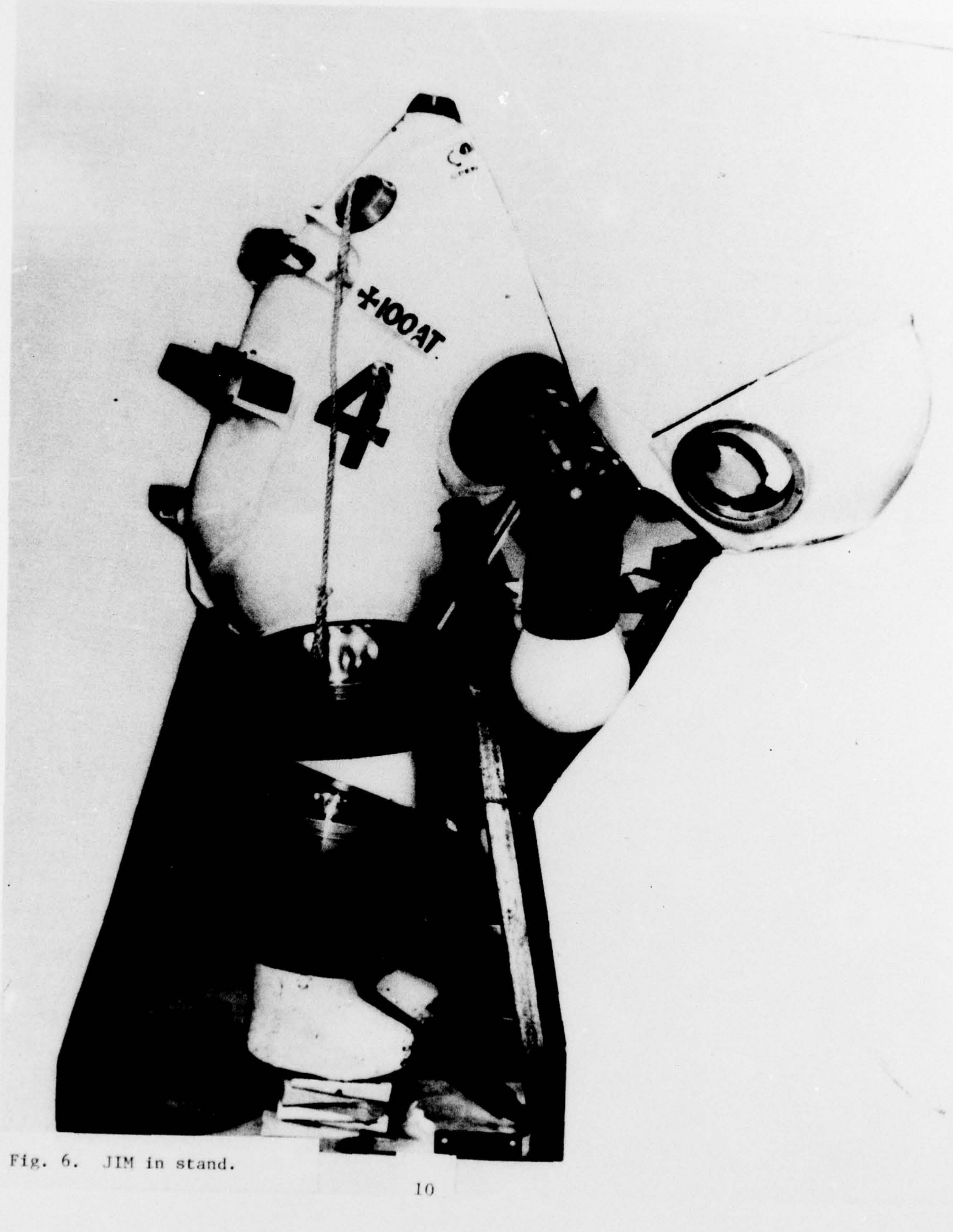

Fig. 6. JIM in stand.

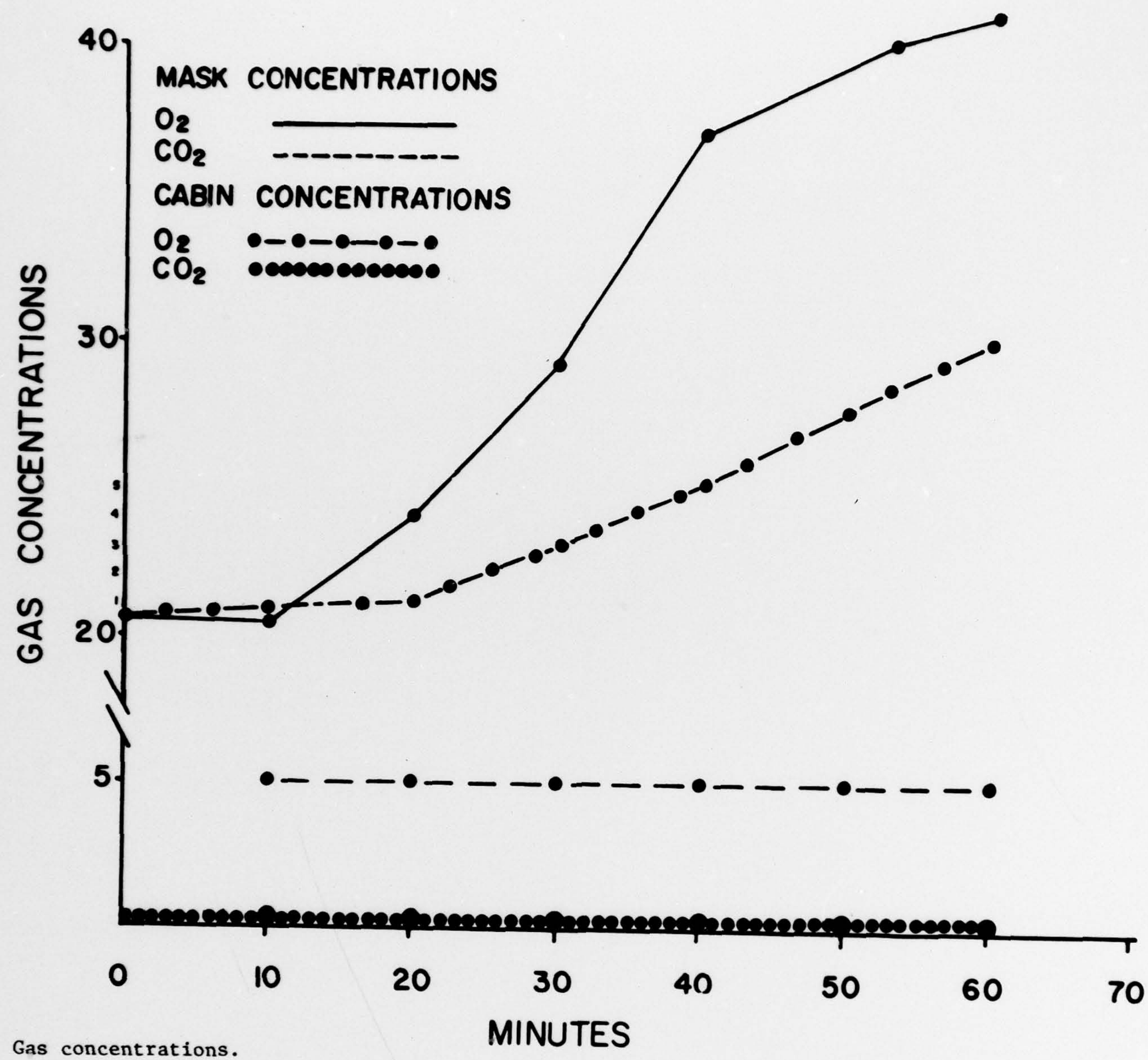

Fig. 7. Gas concentrations.